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11 July 1963

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Ballistic Systems Division
Air Force Systems Command
Norton Air Force Base
San Bernardino, California

Attention: BSRPQ-1

Subject: "Final Report W2SD-19 Structural Test Case M215.06," Report No. MTI-479, dated 15 July 1963, Contract AF 04(647)-243; WS-133A, Stage III Rocket Motor M-57

Reference: Exhibit "D," Paragraph IV.A.3

Gentlemen:

In accordance with Exhibit "D" to Contract AF 04(647)-243, one copy of the subject report is hereby submitted.

Very truly yours,

J. L. Morse

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AF CONTRACT SUPPORT for

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Technical Operating Report
B O B Approval No.________

FINAL REPORT W2SD-19
STRUCTURAL DEVELOPMENT TEST
CASE M215.06

MTI-479

WEAPON SYSTEM 133A

15 July 1963

Contract Number AF 04(647)-243
Exhibit D, Paragraph IV.A.3

Prepared by

HERCULES POWDER COMPANY
CHEMICAL PROPULSION DIVISION
Bacchus Works
Magna, Utah

Prepared for

HEADQUARTERS
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
Los Angeles, California

Report No. MTI-479

Copy No. 10

Date 15 July 1963

FINAL REPORT W2SD-19

STRUCTURAL DEVELOPMENT TEST

CASE M215.06

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FOREWORD

This report outlines work accomplished by the Case Design Group, Chemical Propulsion Division of the Bacchus Works of Hercules Powder Company for the continued development of Rocket Motor M-57, Minuteman Stage III.

Authority for preparation of this report is obtained from Contract AF 04(647)-243, Exhibit D, Paragraph IV.A.3.

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Bacchus Works
Magna, Utah

ABSTRACT

Structural development test W2SD-19, Case M215.06 was conducted at the Bacchus Works, Hercules Powder Company, 26 April 1962 to determine the structural integrity of the Wing II M-57E1 motor case when subjected to combine flight load conditions of axial load, shear load, and bending moment at room temperature.

Case M215.06 failed under the combined effects of an axial load of 24.38 kips, a shear load of 9.285 kips, and a bending moment of 883.5 in.-kips, all which were in excess of required flight design loads. These applied loads were calculated at the forward tangent line where the failure occurred.

From the test results, it was determined that the equivalent axial load was 129.62 kips and that the mode of failure was a circumferential buckling of the forward skirt at the forward tangent line.

It was concluded that the Wing II design is capable of withstanding the present flight performance requirements as defined by Boeing document D2-3877-4. The safety factor, in excess of the design criteria, was determined to be 1.51.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

SECTION I

INTRODUCTION

A. PURPOSE

Structural development test W2SD-19 was conducted as a part of the Wing II Continued Development Program for the design of a lighter weight case for the third stage Minuteman.

The purpose of this test was to gain information in determining the structural integrity cf the Wing II motor case under simulated flight requirements of combined axial load, shear load, and bending moment at room temperature.

The test was conducted 26 April 1962 by Hercules Powder Company at facilities located at Bacchus, Utah.

B. TEST OBJECTIVES

Test objectives were:

(1) To determine the physical capabilities of the forward tangent line area of the Wing II motor case under combined axial load, shear load, and bending moment at room temperature.

(2) To determine modulus of elasticity and Poisson's ratio values for the critical areas of the case at room temperature.

SECTION II

TECHNICAL DISCUSSION

A. TEST SPECIMEN DESCRIPTION

The test specimen was a Wing II motor case, (Ref: HPC drawing 01A00221) Number M215.06, which was constructed of spiralloy. The nominal outside diameter was 37.5 in. The distance between tangent lines was 43.0 in. The case configuration is described in the paragraphs which follow.

1. Cylindrical Section

The cylindrical section of the case consisted of seven layers of 90° windings and six layers of 14.5° helical windings; the thrust termination (TT) port areas were each additionally reinforced with six HTS glass wafers and six TT ply mats. The theoretical thickness was 0.16 in. except in the TT port reinforced area. (The case was pressurized to 50 psig to simulate structural support received from propellant.)

2. Domes

The forward and aft domes were each wound with four layers of 14.5° windings; the nozzle port areas on the aft dome were additionally reinforced with four glass wafers which were 16, 17, 18, and 19 inches in diameter respectively. The minimum theoretical thickness at the tangent line was 0.06 inch.

3. Forward Skirt

The forward skirt build-up consisted of two layers of 14.5° windings, nine layers of reverse 143 weave glass cloth, one layer of 90° windings, and three layers of 90° nylon roving. The nominal wall thickness was 0.17 in., and the length was 12.575 in. measured from the forward tangent line.

4. Aft Skirt

The aft skirt build-up consisted of two layers of 14.5° windings, twenty-two layers of reverse 143 weave glass cloth, one layer of 90° winding and three layers of 90° nylon roving. The nominal wall thickness was 0.313 in. and the length was 6.2 in. measured from the aft tangent line.

A two-cycle cure of the resin was performed in the manufacture of this case. The lamination materials used were Union Carbide's ERLA 2256 resin and HTS 144 ends/in. glass roving.

The forward skirt was internally reinforced with an epoxy-bonded 0.25-in. thick aluminum ring sleeve to ensure that failure occurred in the forward tangent line, or cylindrical section, of the case and not in the forward skirt (Figure 1).

In preparation for the test, a simulated second-to-third stage interstage was attached to the aft skirt, and an R & D section was attached to the forward skirt; both were reinforced.

B. TEST PROCEDURE

After installation of the instrumentation (Figure 2), the assembly was mounted in an upright position in the compression load testing device as shown in Figure 3. This device consisted of three hydraulic rams designated P_1, P_2, and P_3. Ram P_1 was positioned on the base at point 0^o and ram P_2 at 180^o. The force from P_3 was normal to the longitudinal centerline of the case. A representation of the case installed in the test fixture is shown in Figure 4.

The instrumentation was attached to the recorders and checked out for accuracy (polarity, calibration). After this was completed, the simulated flight loads were applied as programmed on the Y-T plots (Figure 5). The actual traces are shown in Figures 6 through 8.

C. TEST RESULTS

The test objectives were satisfactorily met as indicated by the test results outlined below. Test data are shown graphically in Figures 9 through 11 and are listed in Tables I through III.

1. Physical Capabilities

The required loads for this test were:

(1) Axial load = 23.70 kips at room temp

(2) Shear load = 9.00 kips at room temp

(3) Bending moment = 675.00 in. kips at room temp

These loads were the preliminary structural requirements at the time of the test. However, the final (refer to Boeing Document No. D2-3877-4) Wing II structural requirements (maximum q α condition) are:

(1) Axial load = 19.90 kips at 150^o F

(2) Shear load = 6.60 kips at 150^o F

(3) Bending moment = 560.00 in. kips at 150^o F

Therefore, the analysis of this test will be based on final Wing II structural requirements since these are the conditions which the motor must ultimately meet.

The equivalent axial compression load for the above final Wing II requirements at maximum q is 79.6 kips at the environmental temperature of 150° F. (Design surface temperature for Minuteman third stage during first stage operation.) This equivalent load is calculated from the equation:

$$P_{EQ} = P + 2M/R$$

where:

P_{EQ} = Equivalent axial compression load

P = Applied axial compression load

M = Applied bending moment

R = Radius of case

With this surface temperature the strength of Spiralloy degraduates 7 percent. An equivalent ambient structural requirement would therefore be increased from 79.6 kips to 85.59 kips.

The ultimate loads on the case in the area of failure were:

(1) Axial load = 24.38 kips

(2) Shear load = 9.285 kips

(3) Bending moment = 883.50 in.-kips

The equivalent axial compression load for these conditions is 129.62 kips.

The margin of safety, in excess of the design requirements which includes a 1.25 safety factor, is 1.51.

2. Modulus of Elasticity and Poisson's Ratio

The modulus of elasticity and Poisson's ratio were calculated from strain gages located at the forward tangent line and EDI gages measuring circumferential growth.

Gages R and S were the only strain gages that gave reliable data. From this data it was determined that the Poisson's ratio and modulus of elasticity were 0.1875 and 3.02 x 10^6 psi respectively.

A close examination of EDI-5 and EDI-6 indicated that the axial (compression) loads were slightly off center, thereby inducing an additional moment on the case; this moment increased the strain on EDI-5. This misalignment was taken into account by averaging the deflections of these gages. With this consideration the modulus of elasticity, as determined from the EDI gages, was 3.14×10^6 psi.

There is a slight difference in the magnitude of the modulus of elasticity when determined from the EDI data, but the percent difference is well within the expected accuracy of the test equipment. The EDI data tends to verify the correctness of the data obtained from the strain gages.

The mode of failure was circumferential buckling of the forward skirt around the forward tangent line. Since the critical design stress of the forward skirt was less than that of the cylinder, it was expected that this section should fail before the cylindrical section. Figures 12 through 14 are photographs of the failure areas.

SECTION III

CONCLUSIONS

Test data indicate that the case is capable of withstanding the structural requirements.

The modulus of elasticity and Poisson's ratio (3.14×10^6 psi and 0.1875 respectively) are consistent with data from previous tests.

The mode of failure indicates that the forward skirt section of the case is the weakest structural member under this loading condition. This is consistent with the critical design stresses for the forward skirt and cylindrical section.

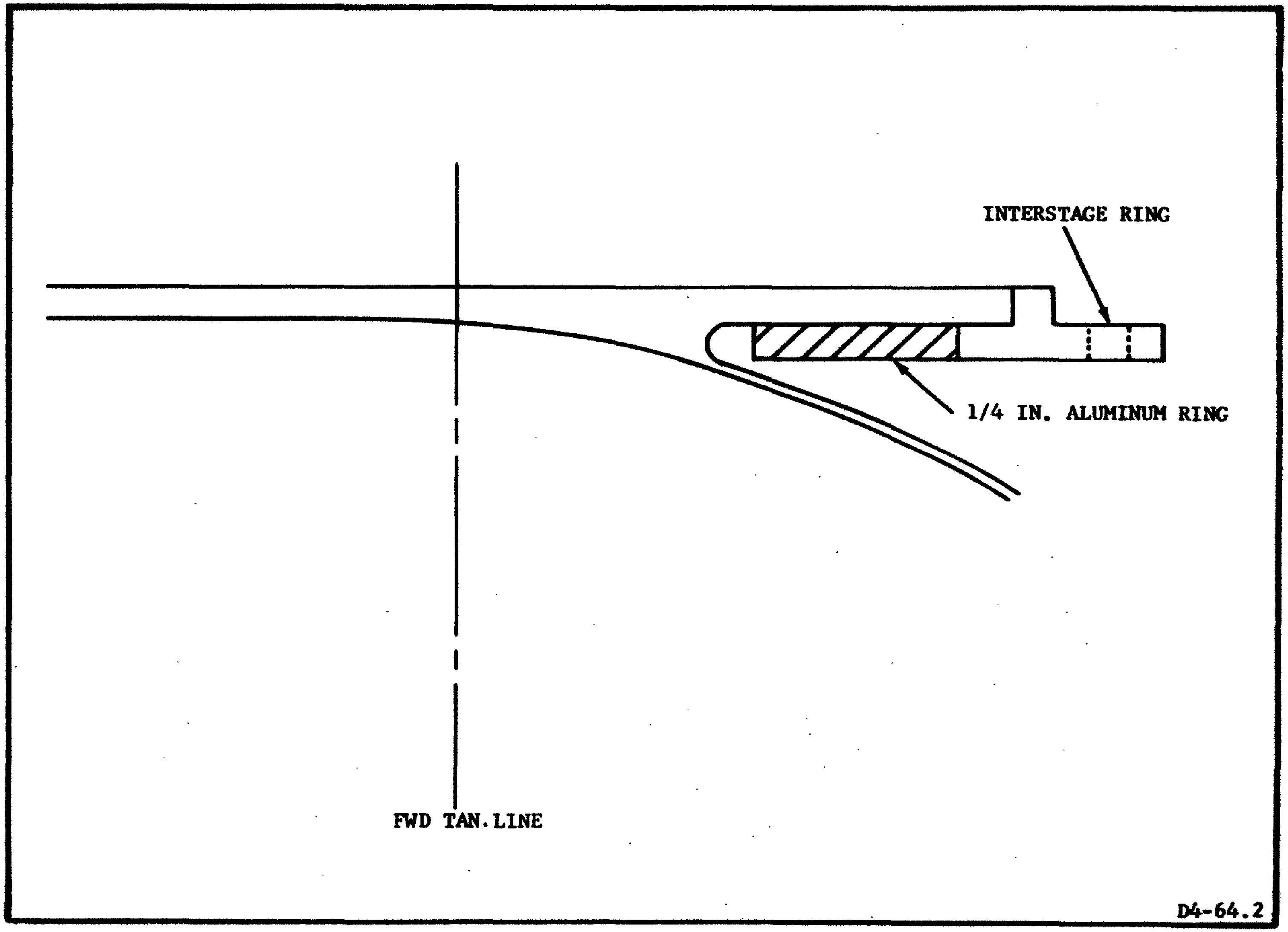


Figure 1. Specimen Reinforcement Diagram

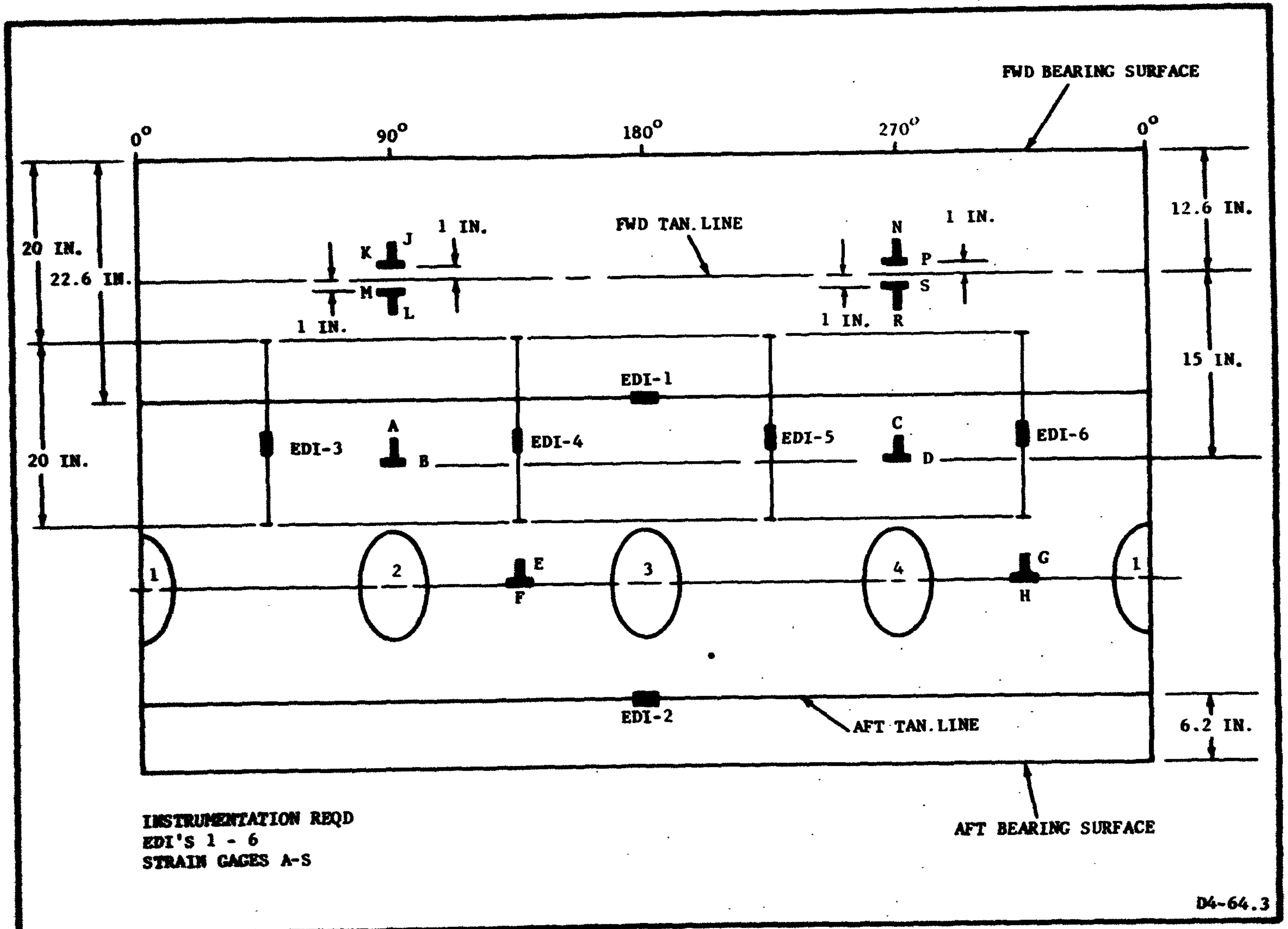
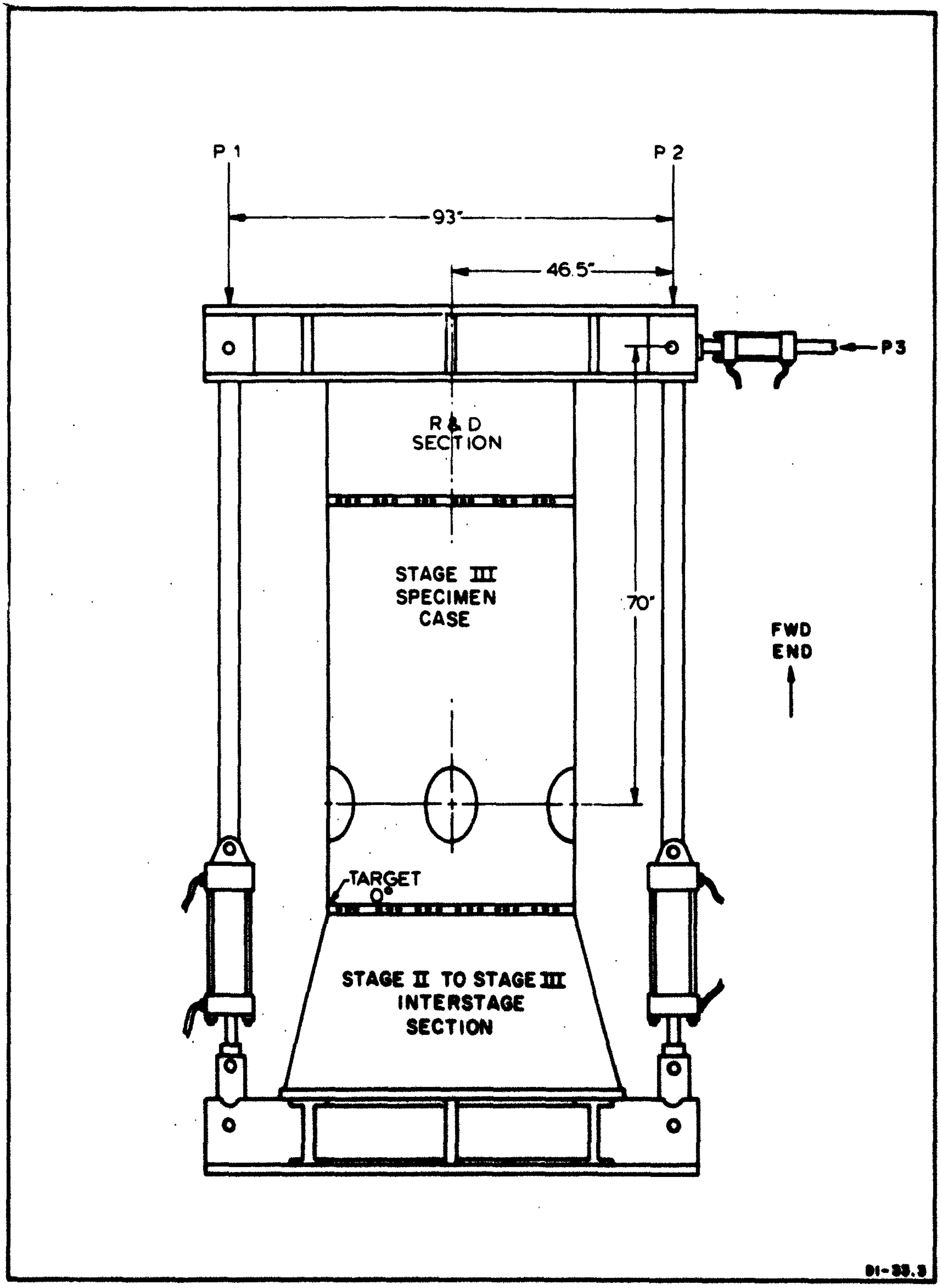


Figure 2. Instrumentation Location



P 1
P 2
93"
46.5"
P3
R & D
SECTION
STAGE III
SPECIMEN
CASE
70"
FWD
END
TARGET
0°
STAGE II TO STAGE III
INTERSTAGE
SECTION
01-35.3

Figure 4. Case in Test Fixture (Representative)

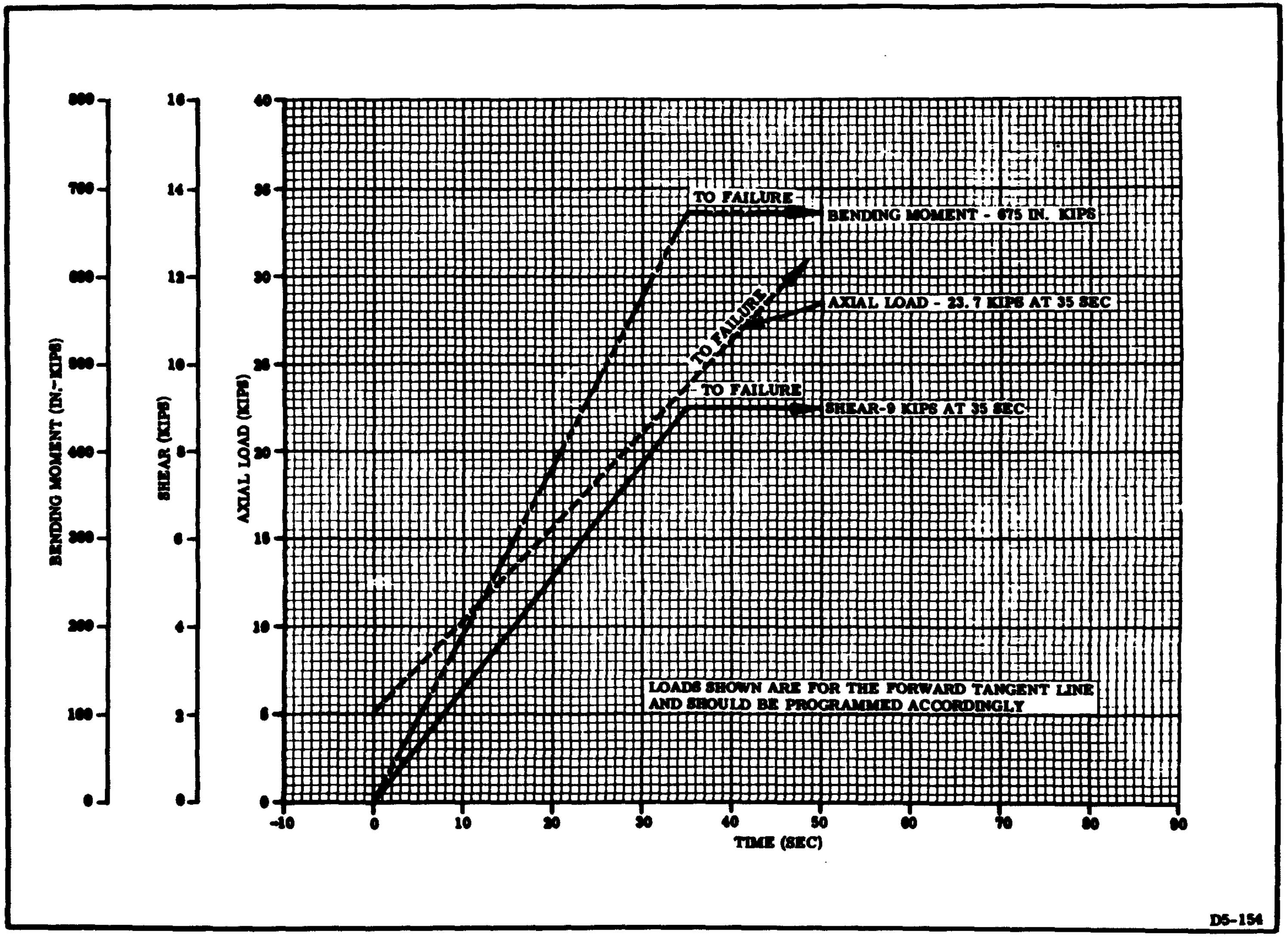


Figure 5. Programmed Load

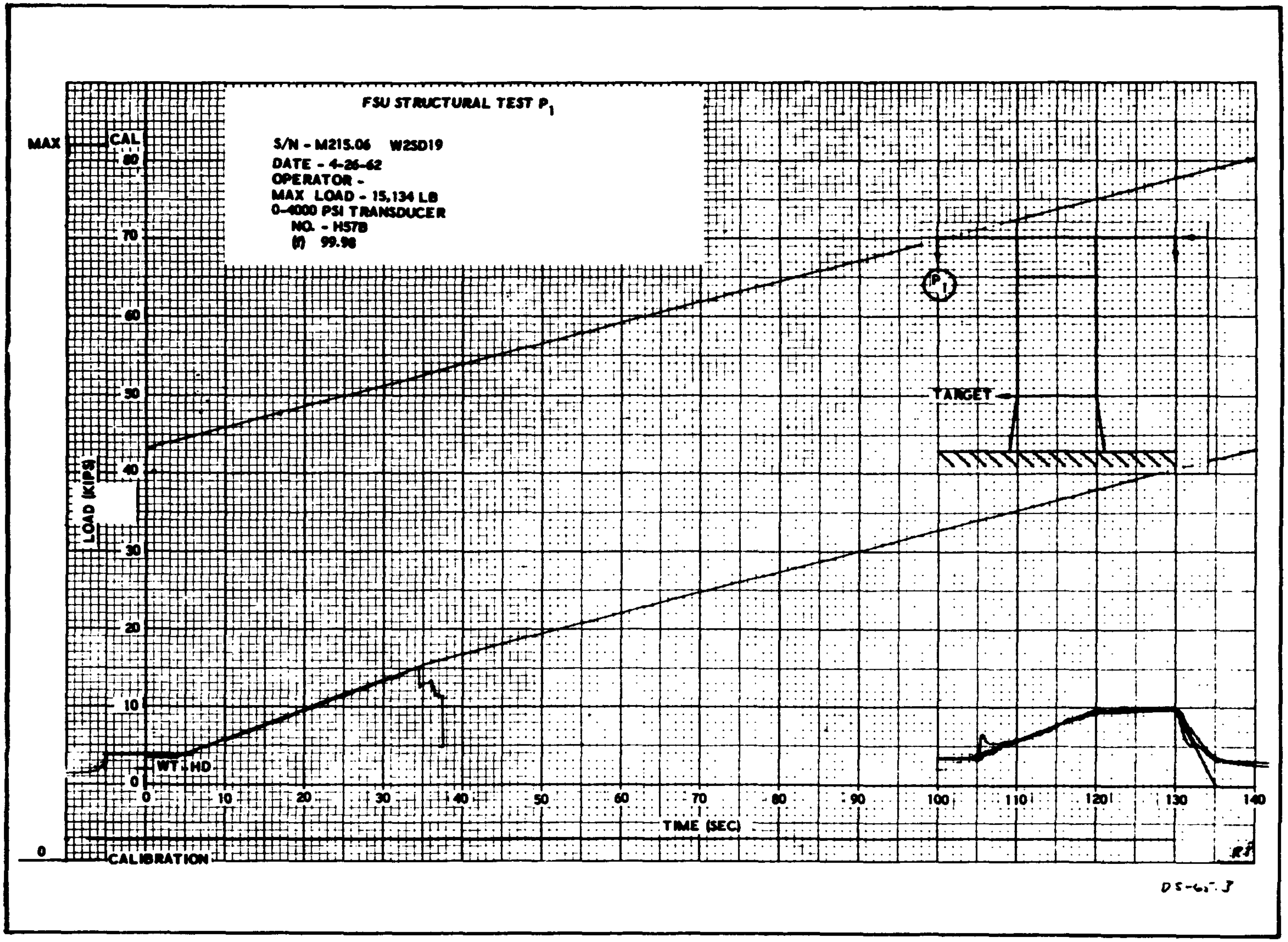


Figure 6. P_1 Compressive Loads vs Time Trace

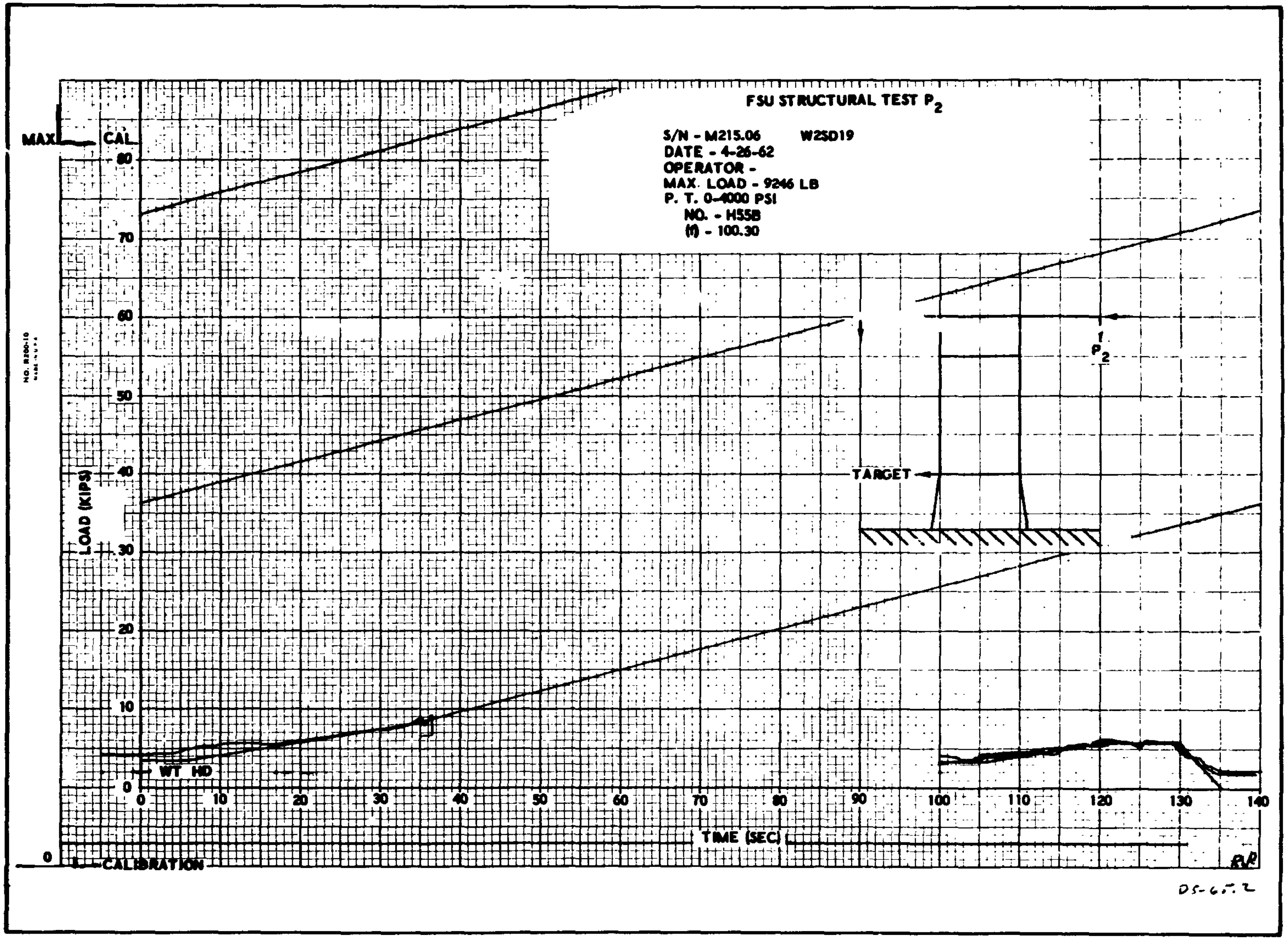


Figure 7. P_2 Compressive Loads vs Time Trace

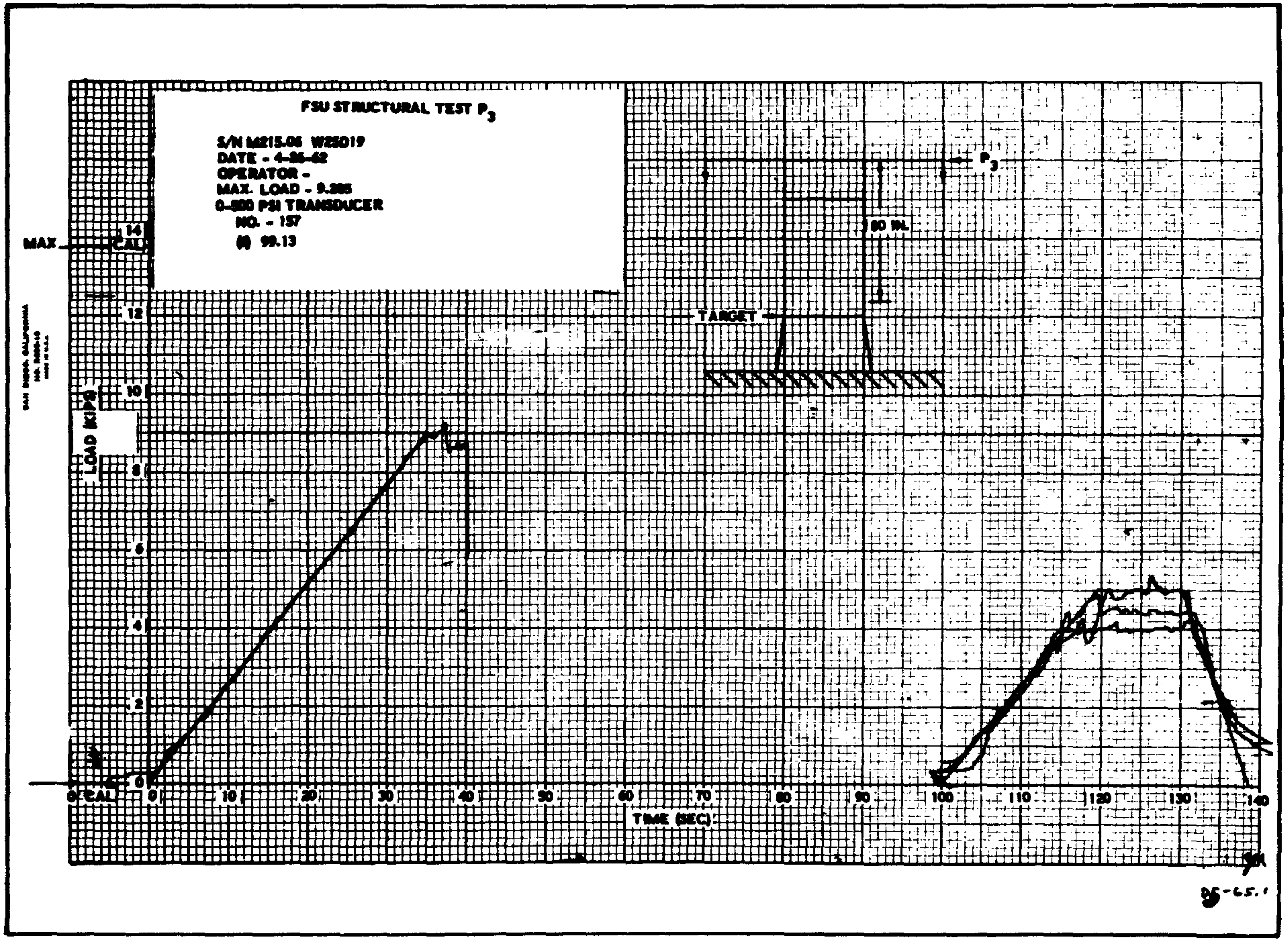


Figure 8. P_3 Shear Load vs Time Trace

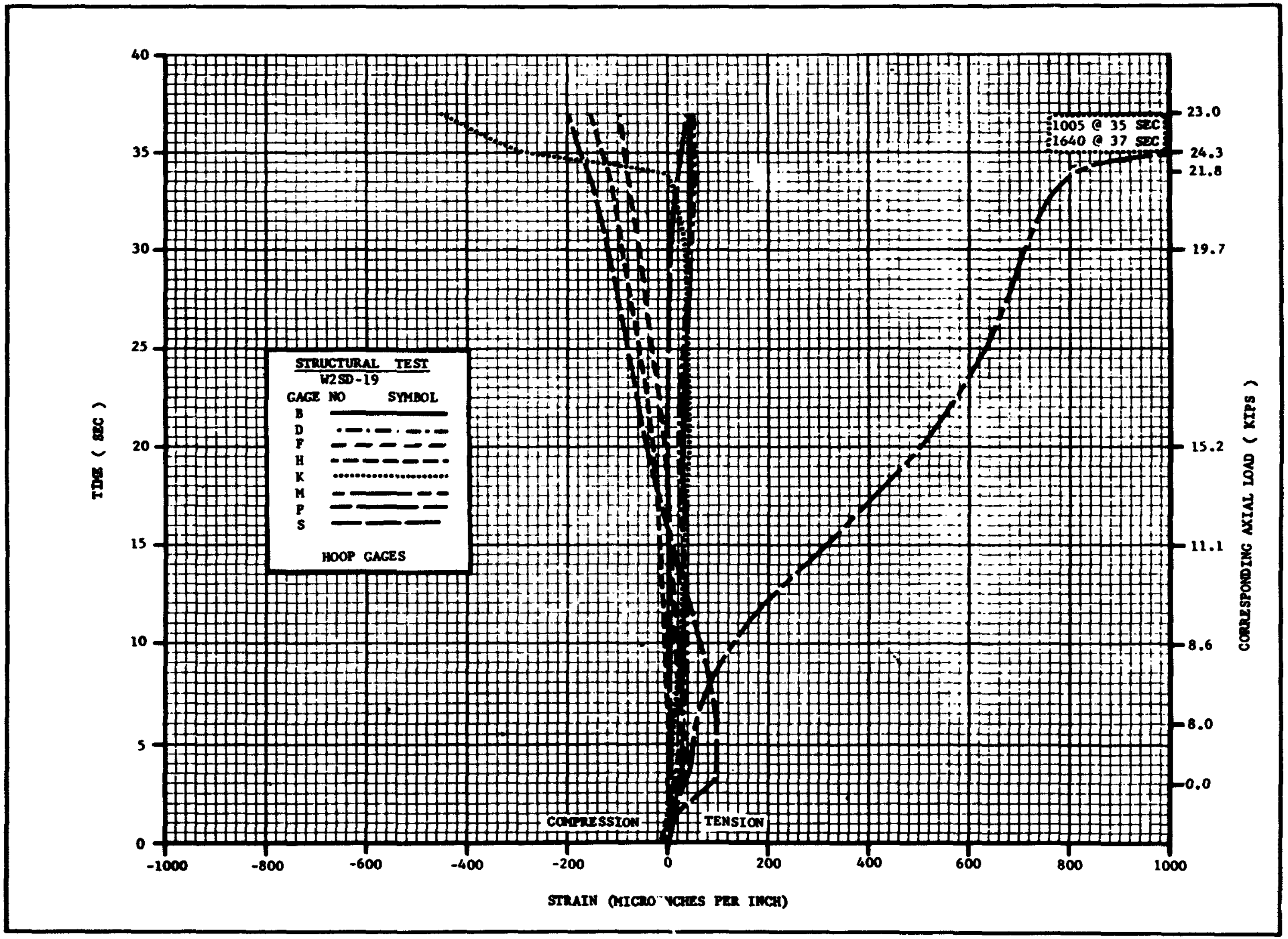


Figure 9. Hoop Strain vs Time

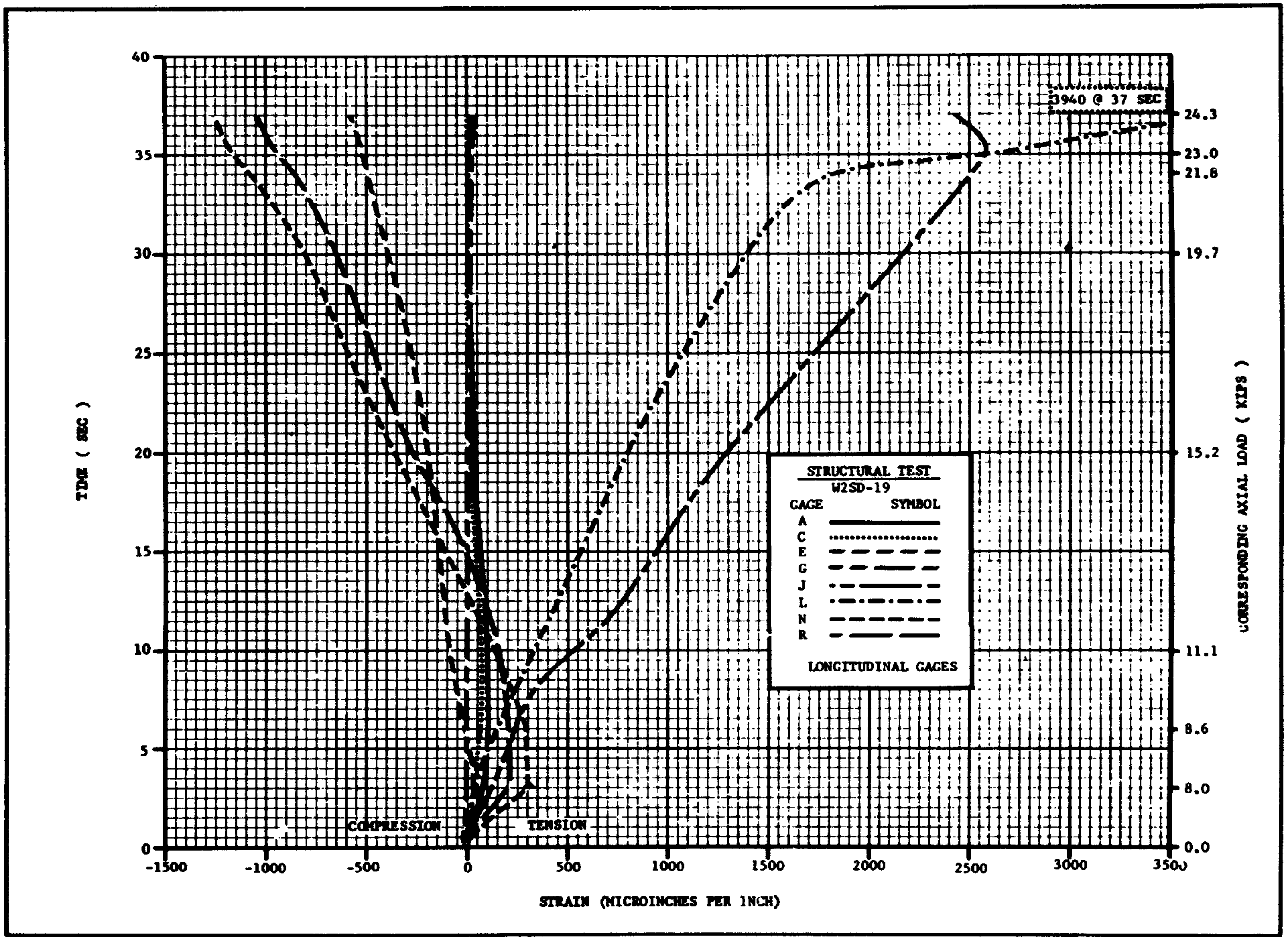


Figure 10. Longitudinal Strain vs Time

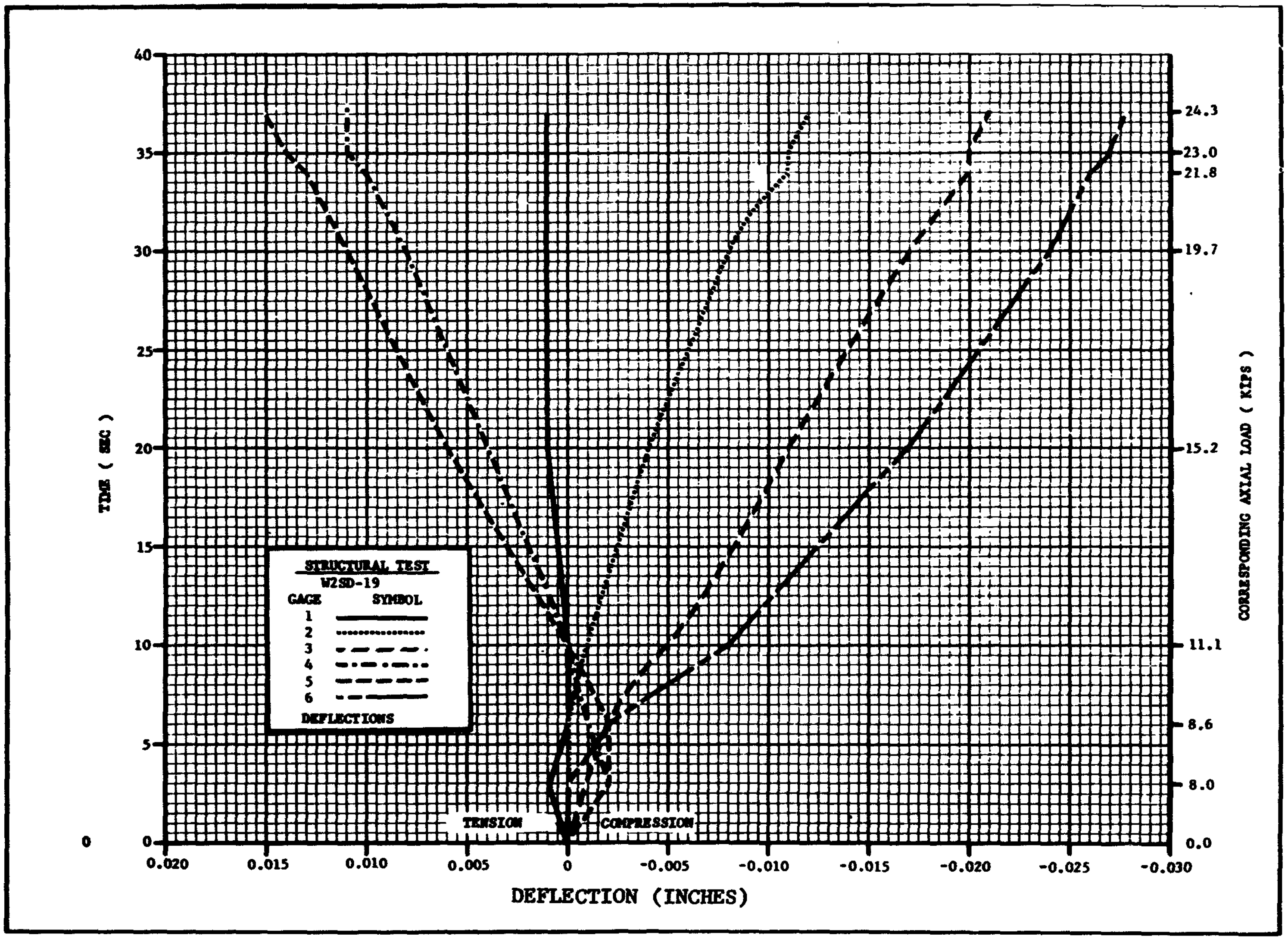


Figure 11. Deflection vs Time

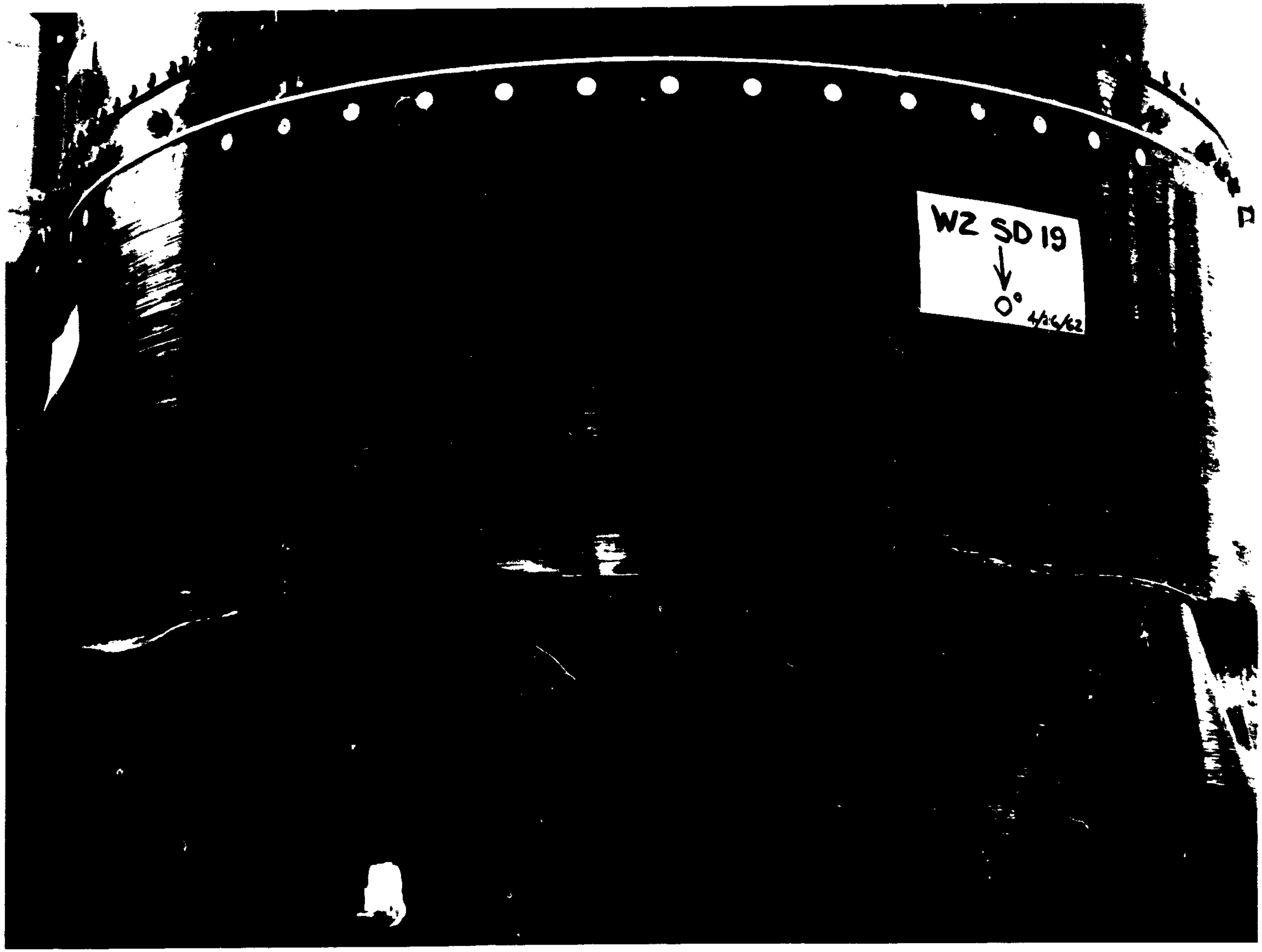


Figure 12. Failure Area, 0^{o}

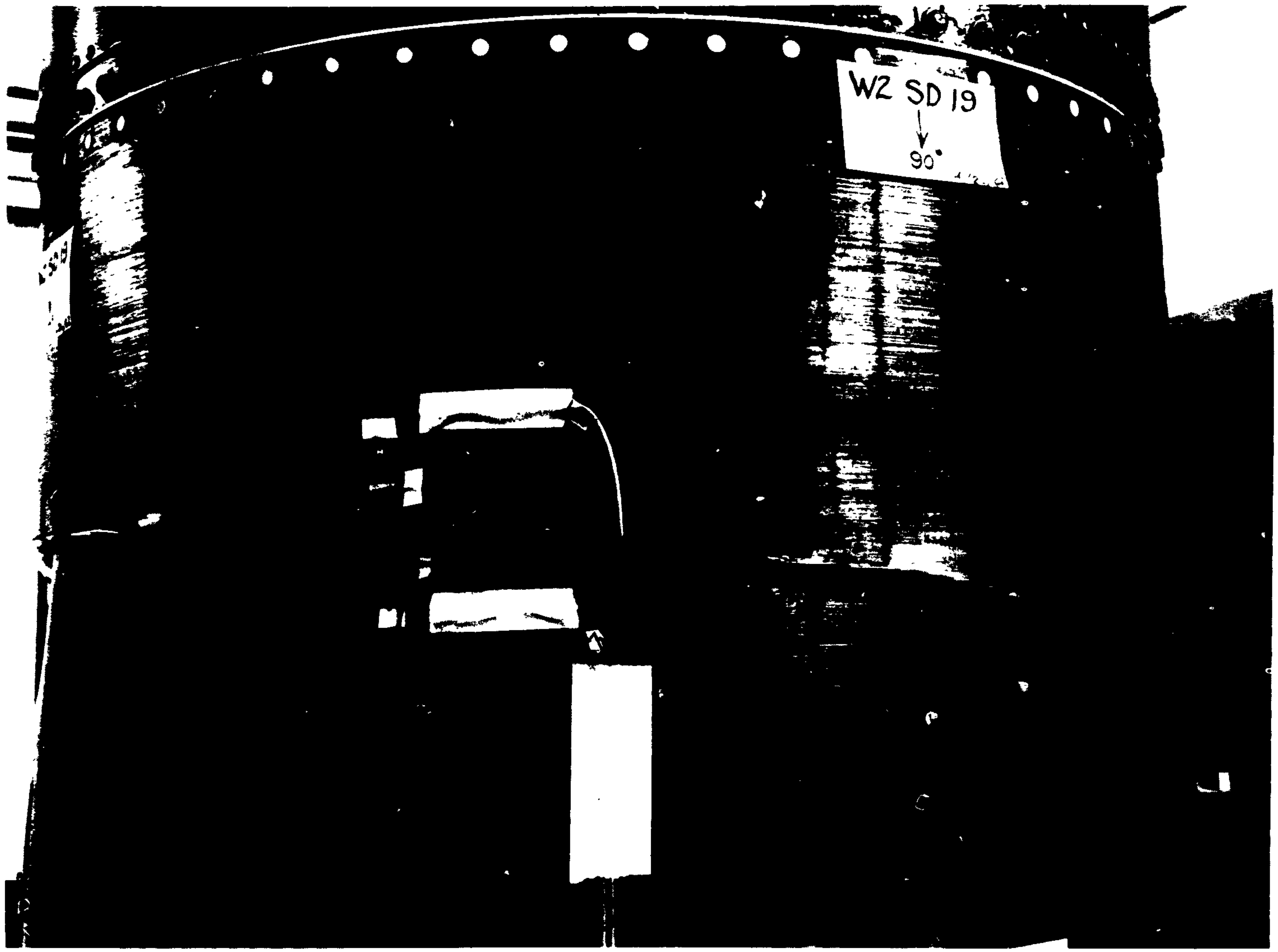


Figure 13. Failure Area, 90^{o}

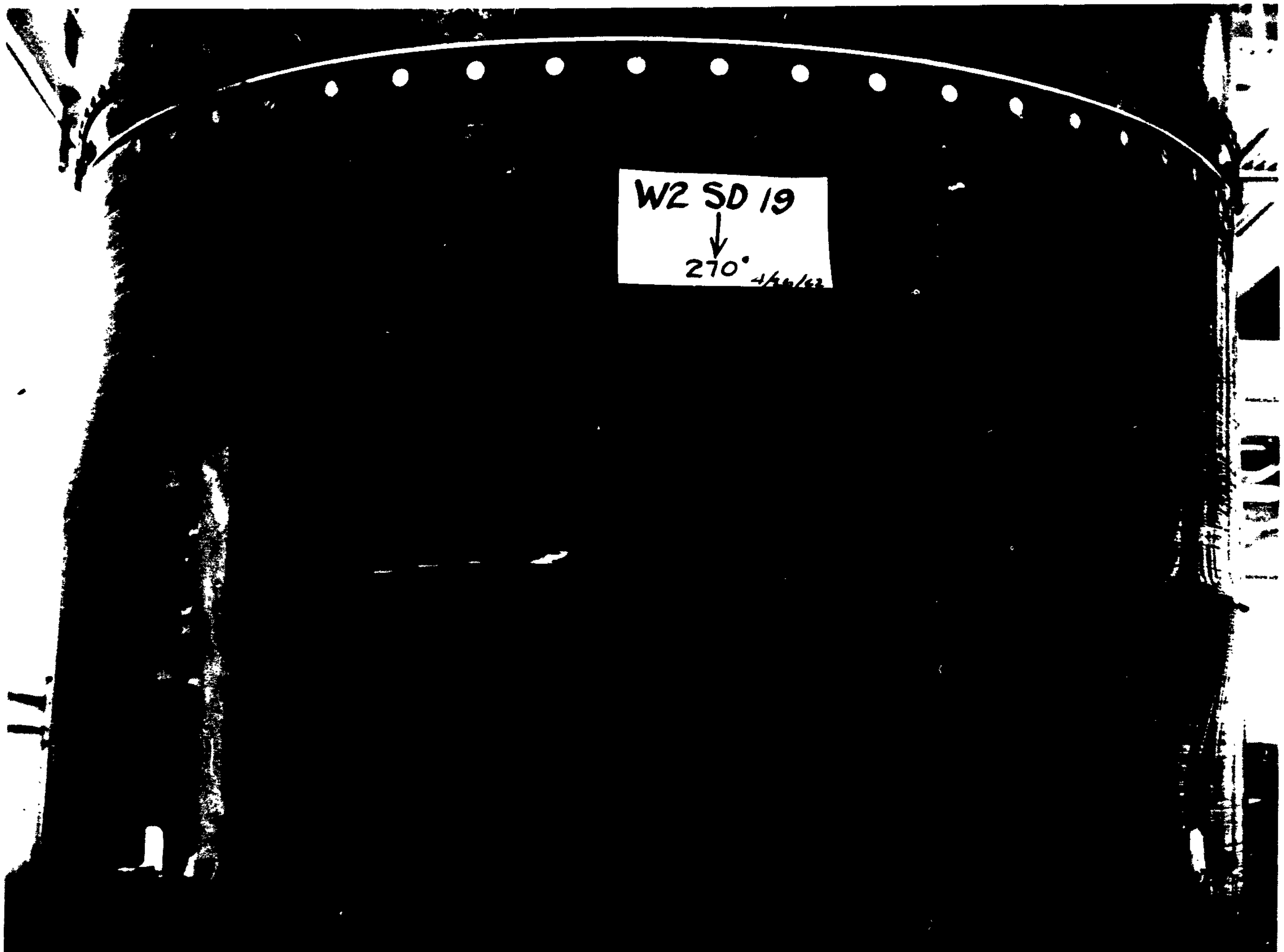


Figure 14. Failure Area, 270°

TABLE I

STRAIN DATA, HOOP DIRECTION

Gage Number	Time (sec)								
	0	0	6	10	20	30	34	35	37
	Axial Load (kips)								
	0	8.0	8.6	11.1	15.2	19.7	21.8	23.0	24.3
B	0	30	30	30	30	45	45	45	45
D	0	15	30	40	20	45	50	50	50
F	0	40	35	15	-5	-55	-80	-85	-95
H	0	5	0	-5	-30	-90	-115	-130	-150
K	0	5	10	30	45	35	5	-273	-450
M	0	50	50	125	510	710	800	1005	1640
P	0	5	5	5	0	5	20	30	35
S	0	95	95	65	-45	-120	-155	-175	-195
MINUS SIGN INDICATES COMPRESSION									

TABLE II

STRAIN DATA, LONGITUDINAL DIRECTION

Gage Number	Time (sec)								
	0	0	6	10	20	30	34	35	37
	Axial Load (kips)								
	0	8.0	8.6	11.1	15.2	19.7	21.8	23.0	24.3
A	0	90	100	100	30	10	0	0	10
C	0	30	70	70	10	0	0	0	0
E	0	30	-10	-90	-200	-400	-500	-520	-590
G	0	0	0	0	0	10	20	20	30
J	0	100	180	550	1290	2170	2515	2575	2425
L	0	30	100	330	800	1400	1750	2615	3940
N	0	300	290	130	-360	-800	-1070	-1160	-1200
R	0	220	200	120	-280	-650	-850	-950	-1040
MINUS SIGN INDICATES COMPRESSION									

TABLE III

DEFLECTION DATA

Gage Number	Time (sec)								
	0	0	6	10	20	30	34	35	37
	Axial Load (kips)								
	0	8.0	8.6	11.1	15.2	19.7	21.8	23.0	24.3
1	0	-0.001	0	0	0.001	0.001	0.001	0.001	0.001
2	0	0	0	-0.001	-0.004	-0.008	-0.011	-0.011	-0.012
3	0	-0.001	-0.002	-0.005	-0.011	-0.017	-0.020	-0.020	-0.021
4	0	0.002	0.001	0	0.004	0.008	0.010	0.011	0.011
5	0	0.002	0.002	0	0.006	0.011	0.013	0.014	0.015
6	0	0	-0.002	-0.008	-0.017	-0.024	-0.026	-0.027	-0.028
MINUS SIGN INDICATES COMPRESSION									

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